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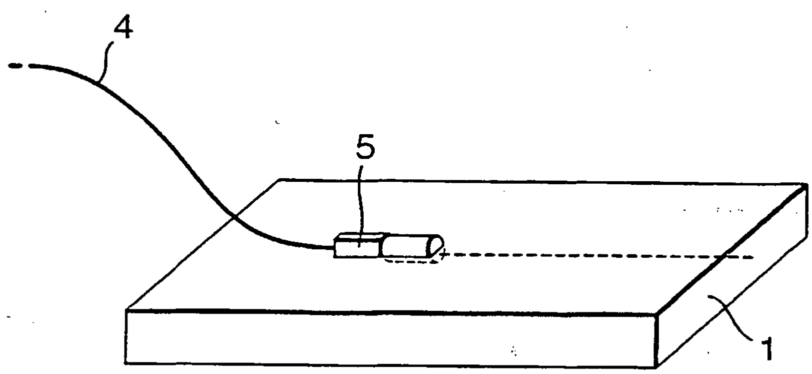
(54) **Title:** FIBRE OPTIC CONNECTOR



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(57) **Abstract:** A method and apparatus for connecting an optical fibre mounted internally inside a composite structure to an external optical fibre. The method uses a 0.5 pitch GRIN lens mounted partly inside the structure with its optical axis offset from that of the internal fibre. The opposite end of the GRIN lens connects optically to the external fibre, also offset by the same amount but opposite side. Light is transmitted between the two fibres via the GRIN lens. Alternatively, the single 0.5 pitch GRIN lens may be two 0.25 pitch GRIN lenses separated by a glass channel. This allows the internal fibre to be mounted deeper inside the structure.

Fibre Optic Connector.

The invention concerns a method of connecting an optical fibre embedded in a structure to an external optical fibre and to a connector for connecting two such fibres.

Optical fibres are embedded into composite structures for several reasons. For example as sensors to measure strain or temperature within a structure such as aircraft wings. It is advantageous to be able to provide connections to these embedded fibres via externally located optical fibres to monitoring equipment, detectors and the like. Signals travelling within the optical fibres are light signals and the term light includes both visible light and other frequencies such as infra red frequencies.

One problem with connecting internal and externally located optical fibres is that of accurate alignment. Several solutions have been proposed including those described in US patent 5,355,429, US patent 6,035,084, US patent 6,035,084, EP 0933659-A1, and a book Fibre Optic Smart Structures, edited by Eric Udd, published by John Wiley & Sons Inc., ISBN 0-471-55448-0, 1995, chapter 6 methods of fibre optic ingress/egress for smart structures, pages 121-153. Often the internal fibre exits the structure at an edge that allows use of edge connectors fixed to the edge of the structure. For other structures it is necessary for the internal fibre to terminate from the structure at its surface away from an edge. Solutions to this include extending the fibre outside the structure when a layered structure is made, e.g. USP 5,355,429.

According to this invention, the problem of aligning an internal and an external optical fibre is solved by use of a graded index (GRIN) lens between the two fibres.

According to this invention a method of connecting an optical fibre within a structure to an external optical fibre comprises the steps of mounting an internal fibre within a structure,
providing a 0.5 pitch GRIN lens having an optical axis and a first and a second face through which the optical axis passes,
optically connecting the first end of the GRIN lens to the internal fibre with the optical axis of the GRIN lens offset from the internal optical fibre,
mounting an external fibre in optical contact with the second end of the GRIN lens with the external fibre mounted offset from the optical axis of the GRIN lens,
the arrangement being such that light can travel between the internal fibre and external fibre through the GRIN lens.

The external fibre may be cemented to the GRIN lens and held in position by a potting compound, or held in a connector separably connected to the structure.

According to this invention a connector for carrying out the method of this invention comprises a structure carrying an internal optical fibre embedded within its bulk,
a 0.5 pitch GRIN lens having input and output faces at either end of an optical axis,
the GRIN lens being mounted partly within the structure in optical contact with the internal fibre and with the optical axis offset from the internal fibre,
and an external optical fibre mounted in optical contact with the GRIN lens and offset from the optical axis,
the arrangement being such that light can travel between the internal and external fibres.

The GRIN lens may be a single 0.5 pitch lens or two 0.25 pitch lenses separated by an optical channel such as a glass rod. This allows the internal fibre to be located much deeper inside the structure. Both 0.5 and 0.25 pitch GRIN lenses are commercially available, e.g. from Nippon Sheet Glass Company. The term pitch relates to the number of cycles that are associated with the sinusoidal trajectory of an optical ray propagating from the input face of the GRIN lens to its output face. The sinusoidal trajectory of an optical ray propagating along a GRIN lens is a consequence of the quadratic refractive index profile of the GRIN lens. An optical ray that propagates along a ray path trajectory equal to one cycle of a sinusoid has a pitch of 1.0. The terms 0.5 and 0.25 pitch GRIN lens is to be taken as including 0.5, 0.25 and functional or nominal or substantial equivalents, because pitch length is frequency dependent.

A 0.25 pitch lens will propagate rays through a quarter of a sinusoid cycle and therefore all rays emanating from a point on the input face of a 0.25 GRIN lens (provided these rays propagate within the numerical aperture of the GRIN lens) will exit the GRIN lens at its output face co-linearly (i.e. they will describe a collimated beam). A 0.5 pitch lens will propagate rays through a half of a sinusoid cycle and therefore all rays emanating from a point on the input face of a 0.5 pitch GRIN lens (provided these rays propagate within the numerical aperture of the GRIN lens) will converge to a conjugate point on the output face of the GRIN lens.

The GRIN lens or lenses may be polished to adjust their optical length to compensate for increased optical path length caused by the offset connections. Alternatively, the GRIN lenses may be selected from a different wavelength specification that will match with the required wavelength's increased path length.

The optical fibres may be single core or multi core fibres, and may be arranged with their optical axis parallel or non-parallel to the optical axis of the adjacent GRIN lens.

The invention will now be described, by way of example only, with reference to the accompanying drawings of which:

Figure 1 is a perspective view of a structure containing an optical fibre and connecting to an external optical fibre; and

Figure 2 is a cross section of Figure 1,

Figure 3 is an enlarged view of the lens in Figures 1, 2, and,

Figure 4 is a cross section of another form of the invention, useful when an optical fibre is located deep below the surface of a structure.

As shown a structure 1 comprises several layers of material such as carbon fibre cloth in a resin matrix formed into a component which may be a part of an aircraft wing. Embedded within the structure is an internal optical fibre 2 placed in position during manufacture of the structure. The fibre is a conventional fibre with a light transmitting core and an outer cladding. Use of structures with embedded optical fibres is a known art; often the structures are termed smart structures because their physical condition and health can be monitored during use. The embedded fibre can detect changes to and within the structure.

A graded index (GRIN) lens 3 is partly embedded in the structure with one end in optical contact with the end of the internal fibre. Outside of the structure 1 is an external optical fibre 4 held in a potting compound 5 in optical contact with the GRIN lens 3. Preferably, the external fibre 4 is held within a separable connector as shown in Figure 4. A capillary tube (not shown) may be used to support the fibre 4 at it junction with the GRIN lens 3.

The lens 3 has a 0.5 pitch measured along an optical axis 6 between end faces 7,8. This lens 3 has the property of taking a point light source input on one end, expanding the light from the source and focussing it back down to a point at the opposite end of the lens. The internal fibre 2 has its core arranged at an offset of -x from the optical axis 6 of the lens 3. Similarly the external fibre has its core offset by +x. This ensures that the (almost) point light from the internal fibre 2 is directed into the core of the external fibre 4 with minimal loss. Due to the two offsets, the optical path within the lens 3 is increased. Therefore it is preferable to polish one end face of the lens 3 to bring the optical path back to 0.5 pitch.

The embodiment of Figures 1-3 is useful when the internal fibre is located close to the component surface. Figure 4 shows how a deeper mounted internal fibre 2 can be connected to an external optical fibre 4. Two 0.25 (nominal) pitch GRIN lenses 11 and 12 are connected by a length of glass channel 13 and to the internal and external fibres 2, 4 respectively. The external fibre 4 may be cemented to the GRIN lens 12 or mounted in a separable connector 14, 15. In the example shown two SELFOC SLS-2.0 GRIN lenses (obtainable from NSG) were used. The lenses 11, 12 however were modified in that their lengths were reduced from a nominal length of 6.631mm to 6.595mm through optically polishing one face of the lens. This was necessary since due to the relatively large lateral offset of the fibres 2, 4 from the optic axis of the lenses, the effective pitch of the lenses was slightly greater than 0.25.

In one example, the propagation path in the glass channel 13 was 20mm, and the internal fibre 2 was embedded at a depth of 2.965mm in a structure 1 thickness of approximately 6mm.

Claims.

1. A method of connecting an optical fibre within a structure to an external optical fibre comprising the steps of mounting an internal fibre within a structure, providing a 0.5 pitch GRIN lens having an optical axis and a first and a second face through which the optical axis passes, optically connecting the first end of the GRIN lens to the internal fibre with the optical axis of the GRIN lens offset from the internal optical fibre, mounting an external fibre in optical contact with the second end of the GRIN lens with the external fibre mounted offset from the optical axis of the GRIN lens, the arrangement being such that light can travel between the internal fibre and external fibre through the GRIN lens.

2. The method of claim 1 wherein the GRIN lens is a single 0.5 nominal pitch lens.

3. The method of claim 1 wherein the GRIN lens is formed by two 0.25 nominal pitch lenses 11, 12 separated by an optical channel 13.

4. The method of claim 1 wherein the external fibre is held in a connector separably connected to the structure.

5. A connector for carrying out the method of this invention comprising: a structure carrying an internal optical fibre embedded within its bulk, a 0.5 pitch GRIN lens having input and output faces at either end of an optical axis, the GRIN lens being mounted partly within the structure in optical contact with the internal fibre and with the optical axis offset from the internal fibre, and an external optical fibre mounted in optical contact with the GRIN lens and offset from the optical axis, the arrangement being such that light can travel between the internal and external fibres.

6. The connector of claim 5 wherein the GRIN lens (3) is a single 0.5 nominal pitch lens.

7. The connector of claim 5 wherein the GRIN lens (3) is formed by two 0.25 nominal pitch lenses 11, 12 separated by an optical channel 13.

8. The connector of claim 5 wherein the external optical fibre 4 is connected to the GRIN lens (3, or 12) by a separable connector (14, 15).

9. The connector of claim 5 wherein the external optical fibre 4 is connected to the GRIN lens (3, or 12) by an optical cement (5).

10. The connector of claim 5 wherein the optical fibres are multi core fibres.

11. The connector of claim 5 wherein the optical fibres are single core fibres.

Fig.1.

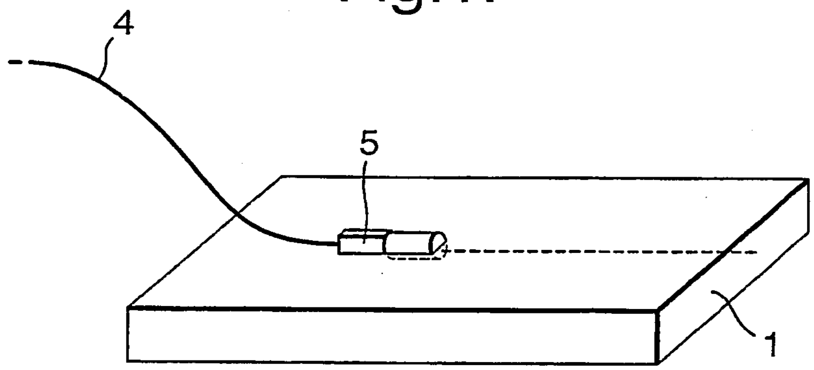


Fig.2.

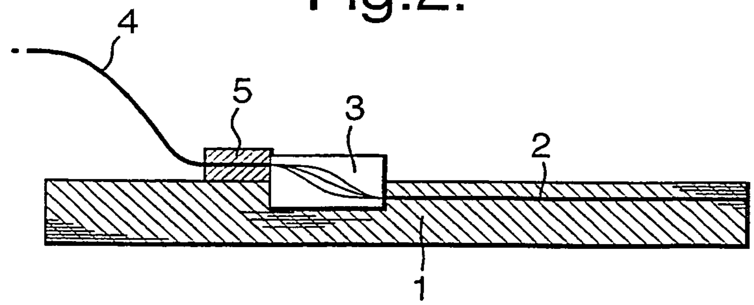


Fig.3.

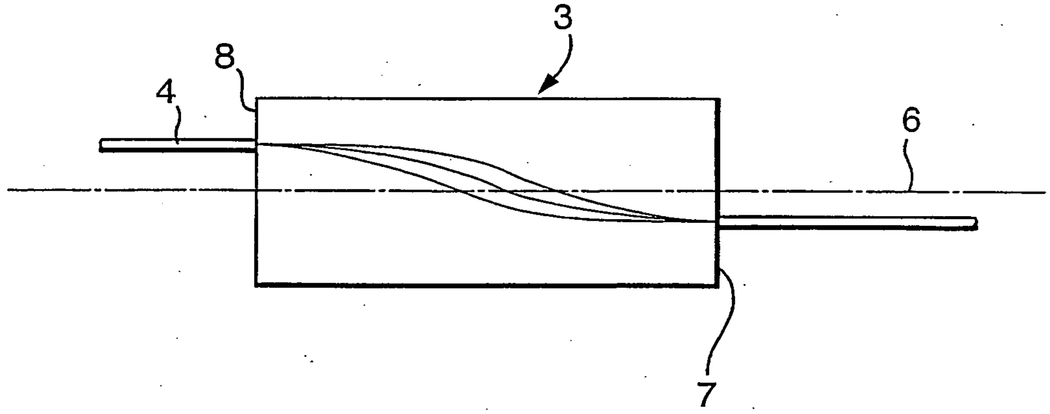
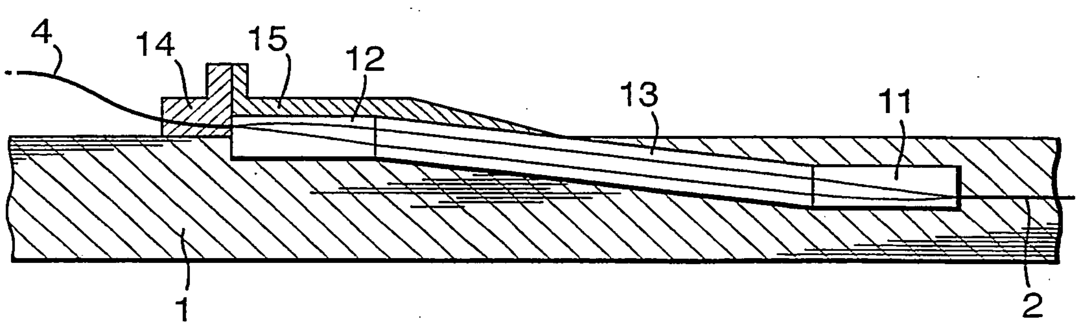


Fig.4.



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(54) Title: FIBRE OPTIC CONNECTOR

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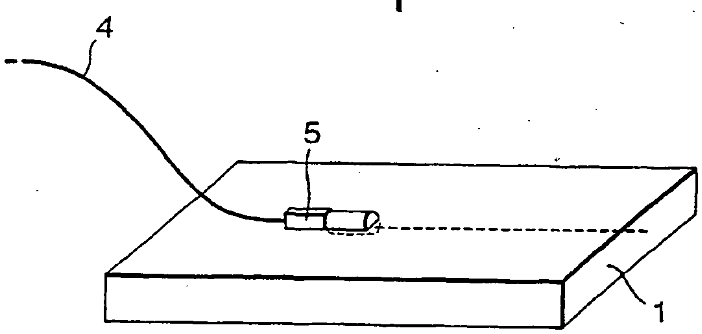

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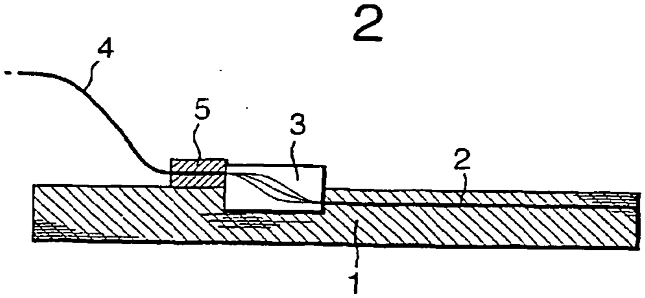

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WO 2003/098301 A3

Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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INTERNATIONAL SEARCH REPORT

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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 39 32 655 A (SIEMENS AG) 11 April 1991 (1991-04-11) abstract; claims 1-8; figures 1,2 ---	1,5
A	WO 01 81961 A (STANDARD MEMS INC ;FRICANO GLENN J (US); TRIMMER WILLIAM (US)) 1 November 2001 (2001-11-01) abstract; figures 1-3 ---	1,5
A	US 5 355 429 A (LEE NICHOLAS A ET AL) 11 October 1994 (1994-10-11) cited in the application abstract; figures 1-12 ---	1,5
A	US 6 035 084 A (DUNNE JAMES P ET AL) 7 March 2000 (2000-03-07) cited in the application abstract; figures 1-5 --- -/--	1,5

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
15 December 2003	22/12/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Malic, K

INTERNATIONAL SEARCH REPORT

International Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 933 659 A (JDS FITEL INC) 4 August 1999 (1999-08-04) cited in the application abstract; figures 1-9 -----	1,5

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
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